THE DEPOSITION OF THE CARBONIFEROUS FORMATIONS OF THE NORTH SLOPE OF THE OZARK UPLIFT.[1]

INTRODUCTION.

THE following study is the outgrowth of field-work performed by A. F. Smith[2] and the writer in the spring of 1902 for the Missouri Bureau of Mines and Geology. Miller county was carefully mapped,

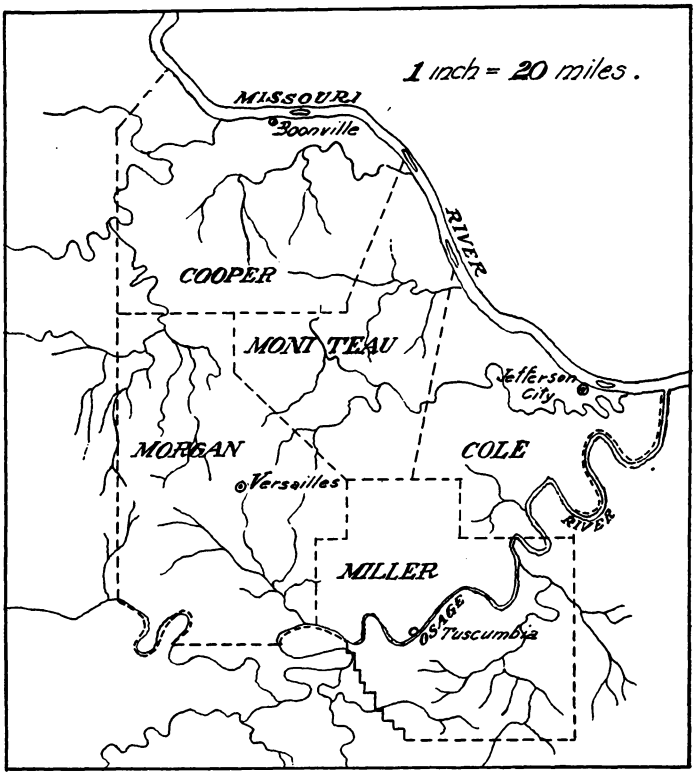

FIG. 1.—Sketch map of North Slope of the Ozark Uplift.

while Morgan, Moniteau, Cole, and Cooper counties were visited. These counties form the center of the north slope of the Ozarks. (See Fig. 1.)

[1] Published by permission of the Director of the Missouri Bureau of Mines and Geology.

[2] Acknowledgments are due A. F. Smith for valuable suggestions.

TOPOGRAPHY.

The northern flank of the Ozark uplift is a plain sloping gently to the north. Its level surface is due to Tertiary peneplanation.[1] In the vicinity of the major streams the plain is intimately dissected and the topography is mature.

STRATIGRAPHY.

The stratigraphy is summarized in the following table:

Recent.	Osage alluvium.	
Pleistocene.	Glacial bowlders in Osage alluvium.	
	Unconformity.	
Pennsylvanian	Graydon sandstone. Massive, medium-grained sandstone, more or less conglomeratic. Lithologically scarcely to be distinguished from the Pacific sandstone. 0–75 feet thick.	
	Coal-Measure shale. Shale, more or less conglomeratic, bituminous and cannel coal and limestone. 0–156 feet thick.	
	Saline Creek cave-conglomerate. Unassorted conglomerate composed of arenaceous or calcareous shale containing pebbles and blocks of older formations. Grades into Coal-Measure shale. 0–60 feet thick.	
	Unconformity.	
Mississippian	Burlington limestone. White, coarse-grained, fossiliferous limestone. 0–108 feet thick.	
	Chouteau limestone. Buff, argillaceous limestone. 0–85 feet thick.	
	Unconformity.	
Undifferentiated Cambro-Ordovician	Pacific sandstone.	Dolomites, sandstones, and shales. Referred to below as "Cambro-Silurian."
	Jefferson City formation.	
	St. Elizabeth formation.	
	Gasconade limestone.	
	Gunter sandstone.	
	Unconformity.	
Probable Cambrian	Proctor limestone.	

It is the purpose here to describe the sequence of events connected with the deposition of the Carboniferous, and particularly the Pennsylvanian, formations, rather than the detailed stratigraphy.[2]

[1] MARBUT, *Missouri Geological Survey*, Vol. X, p. 27.

[2] For stratigraphy see BALL AND SMITH, "The Geology of Miller Co.," *Missouri Geological Survey*, 2d ser., Vol. I, pp. 23–122.

THE DEPOSITION OF THE CARBONIFEROUS FORMATIONS.

The Chouteau and Burlington.—The Chouteau and the Burlington limestones lie unconformably upon the Cambro-Silurian dolomites, the Burlington apparently overlapping the Chouteau. The pre-Burlington land surface was of the same order of ruggedness as the present, and the sea advanced over the land too rapidly to cut it into a submarine plain. North of the Osage River Burlington outliers occur both on the hilltops and in the valley below. South of the Osage the present land surface is lower than the Burlington sea bottom, and only residual Burlington bowlders are now found there. Since this old topography was not base-leveled, several uplifts may have occurred between the Trenton and Burlington.

Residual Burlington chert indicates that the early Carboniferous sea covered all Missouri but the country surrounding the St. Francois Mountains. If land existed around them, it must have been incapable of furnishing large amounts of clastic material to the sea. Fossils show that the sea was teeming with animals too fragile to resist heavy waves, but requiring gentle currents to furnish food material.

The interval between the Burlington and Coal-Measure deposition.—Elevation, with contemporaneous erosion, produced, by the time of deposition of the Coal-Measure rocks, a topography similar in ruggedness to the present topography. The thickness of the Burlington limestone appears to have varied from 40 to 180 feet.

At the beginning of the elevation the rivers had renewed strength, but until the Burlington limestone, which is lacking in clastic grains, was cut through, erosive tools were doubtless lacking. Still solution occurred on a large scale, as shown by the deposition of the Saline Creek cave-conglomerate and the Coal-Measure shale in joints, enlarged by solution, in sinks and in caves. The inter-Carboniferous conditions were doubtless somewhat akin to those now existing in limestone regions in the tropics, in which we know caves and sinks to be very abundant. The extent to which observation shows solution occurred warrants a somewhat full discussion of the principles of solution.

The conditions favoring solution[1] are:

[1] The rest of this section is the application to a particular area of principles set forth in VAN HISE'S forthcoming treatise on *Metamorphism.*

1. *High carbon-dioxide content.*—The limestone deposition of the Mississippian period, as Chamberlin has shown, set free a large amount of carbon dioxide. This carbon dioxide acted as a blanket to keep in the sun's heat, and greatly increased the power of water to dissolve limestone.

2. *High barometric pressure.*—Carbon dioxide being over one and one-half times as heavy as air, its presence would increase the barometric pressure, thus proportionately increasing the chemical activity of gases and liquids.

3. *High and constant temperature.*—In post-Burlington times the Ozark region was an island about 160–200 miles in diameter. Because of its insular position and the high carbon-dioxide content in the atmosphere, the climate must have been humid, equable, and warm. The plants of the Coal-Measure shale indicate a tropical or subtropical climate. The chemical activity of water at 0° C. is almost nil, but with increase in temperature the solvent power increases out of all proportion to the thermal rise. Since seasonal changes were doubtless slight, solution could work the year around.

4. *High humidity.*—The seas surrounding the Ozark island would furnish abundant moisture both to abstract the carbon dioxide from the air and to bear it through the rocks.

5. *Soluble material to act on.*—The purity of Burlington limestone and the porosity of the Cambro-Silurian dolomites render each easily soluble, and caves, sinks, and natural bridges are common in the Ozark region today. As the Burlington limestone is coarse and the Cambro-Silurian dolomites medium-grained, the relative solubility of the latter would be increased. As an illustration of this the crinoids, the largest calcite grains in the Burlington limestone, are the last to be silicified in the metamorphism to chert.

6. *Moderate topographic relief.*—Moderate topographic relief furnishes conditions favorable to slow percolation and unfavorable to excessive mechanical erosion. The presence of post-Burlington sink-holes on the upland and in the adjacent valleys indicates that the level of post-Burlington ground water, and in consequence the topography, was broadly similar to that of the present day.

7. *Thick mantle rock.*—Thick mantle rock tends to retard run-off and to increase the time in which solvent waters may act. Solu-

tion doubtless formed a deep residual soil, partially from the insoluble residue of the Burlington limestone, but largely from that of the Cambro-Silurian dolomites and sandstones.

8. *Abundant plant and animal life.*—Plants and animals are important, in producing, directly or indirectly, carbon dioxide. The tropical or subtropical climate, the humidity, and the abundant carbon dioxide favored abundant plant life.

The chief underground circulation must have been to the north and northwest to the Coal-Measure sea, following the present and doubtless the former dip of the strata. Judging from the pre-Coal-Measure sink-holes, the water level must have been from 40 to 125 feet below the pre-Coal-Measure surface. The surface circulation was probably bounded below by the intercalated shales of the Cambro-Silurian formations. At the beginning of pre-Coal-Measure erosion the surface circulation may have been but 150–250 feet deep.

Because of the ready solubility of the Burlington limestone and, perhaps, of initial depressions in the upper surface of this formation along pre-Burlington drainage lines, arising from the unequal thickness of the Burlington cover, erosion tended to exhume the old valleys. They may be referred to as "resurrected valleys"—a term kindred to "resurrected mountains" (Davis).

Deposition of the Saline Creek cave-conglomerate.—The oldest formation of the Pennsylvanian, the Saline Creek cave-conglomerate, lies in joints, enlarged by solution, in sink-holes, and in cave-galleries in the Burlington and Cambro-Silurian limestones and dolomites. At the exposure on Tavern Creek the formation is at least 60 feet deep and includes blocks 18 feet long. The Cambro-Silurian limestone dips toward the sink for 150 feet on either side. A cistern at Mr. Ramsey's follows a joint filled with Saline Creek cave-conglomerate 18 feet into a filled cave-gallery 11 feet across. The bowlders of the Saline Creek cave-conglomerate are noticeably local in origin, and are not only too large to have been transported by any streams possible with the supposed topography, but many of them are of such soft material that they could not have been carried far. The composition of the shales corresponds in a general way in lime and sand content with that of the surrounding rocks.

In consequence, it is inferred that these solution cavities were

filled partially by an in-washing of the surrounding soils, and partially by the caving-in of walls of the sink-holes and caves due to sapping by differential solution.

The unconformity between the Mississippian and Pennsylvanian is widespread throughout Missouri.[1] On the north slope of the Ozarks the unconformity is shown by (1) basal conglomerates, (2) discordance of bedding, and (3) general field relations, the Saline Creek cave-conglomerate being deposited on both the Burlington limestone and the Cambro-Silurian formations.

Deposition of the Coal-Measure shales.—The deposition of the Saline Creek cave-conglomerate continued until the region subsided practically to sea-level. Then began the deposition of the Coal-Measure shales. Clay washed into those depressions not filled by the Saline Creek cave-conglomerate. At times muck with a small clastic content was deposited, later to consolidate into cannel coal. The sink-holes clogged up with clay became fit sites for swamps. Coal beds 30–40 feet thick resulted (McClure Prospect 32 feet, Knowall 35 feet). Locally the sea encroached on the land, and argillaceous, fossiliferous limestones were deposited. That the basins of deposition were very local is shown by the dissimilarity of the rocks of neighboring Coal-Measure basins and the impossibility of correlating individual strata.

At the Republic Mine the following is a section from the underlying Jefferson City (Cambro-Silurian) formation up:

28 feet bituminous coal and shale interlaminated.

10 feet argillaceous limestone, fossiliferous — *Productus semireticulatus.* *Productus cora.* *Spirifer cameratus.* *Spirifer rockymontanus.*

4 feet more or less calcareous shale.

4 feet variegated chert, fossiliferous.

At the William Shelton Prospect, three miles away, the succession up from the same formation is:

50 feet shale, grading into

40 feet cannel coal.

Many equally striking cases might be cited.

[1] *Missouri Geological Survey*, Vol. VII, p. 438.

The Coal-Measure shales were deposited in sinks, enlarged joints, and cave-galleries—a fact indicated by their small area and relatively great depth. The Knowall Prospect penetrated 85 feet of Coal-Measure shale. Four drill-holes in the immediate vicinity penetrated only the Cambro-Silurian dolomites. A shaft in the Gageville Mine passed through 50 feet of Cambro-Silurian dolomite and then 10 feet of Coal-Measure shale, the contact being very irregular (Fig. 2). This appears to be a cave-gallery, and may con-

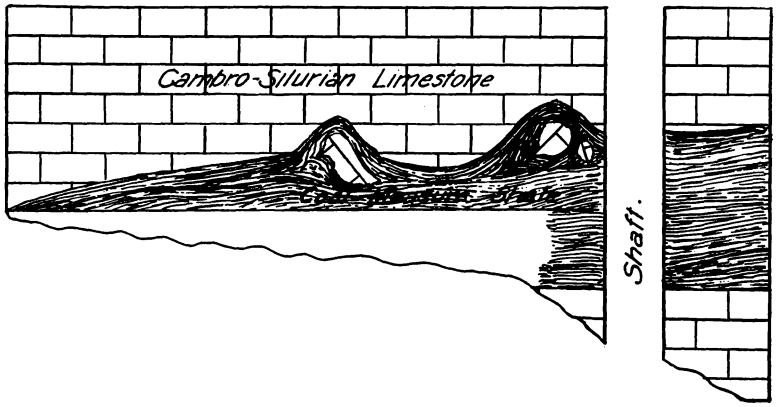

FIG. 2.—Cave-gallery filled with Coal-Measure Shale, Gageville Mine.

nect with another shale outcrop in the valley below. Coal-Measure shale occurs in a pocket 50 feet in diameter in a valley at the Son Prospect. On the hillside a shaft passed through 4½ feet of Cambro-Silurian dolomite into the shale (Fig. 3). Further evidence is the fact that the Cambro-Silurian dolomites dip, as a rule, toward the shale outcrops, often as much as 30°.

Deposition of the Graydon sandstone.—The exact time-relations between the Coal-Measure shale and the Graydon sandstone is as yet not certain, but the weight of evidence seems to make the Graydon sandstone the younger. However, the two may have been contemporaneously deposited in various parts of the country, or the sandstone may have been deposited at two or more times.

The Graydon sandstone exposures rest on the Burlington limestone and on the Cambro-Silurian formations. In the little dissected plain it occurs in many small round areas; in the more dissected

regions the exposures are fewer, possess a trail-like form, and are largely confined to valleys. From the latter conditions we infer that in the vicinity of the river, erosion has removed all but the Graydon sandstone deposited in deep gulches. These again seem "resurrected" valleys. The inclosing Cambro-Silurian walls are undisturbed, and seem to delimit normal erosion valleys.

The Graydon sandstone appears to have been deposited upon a surface somewhat like the present, with the greatest dissection in the vicinity of the Osage River. If important valleys of Graydon age had existed in the upland, we should find in this little dissected

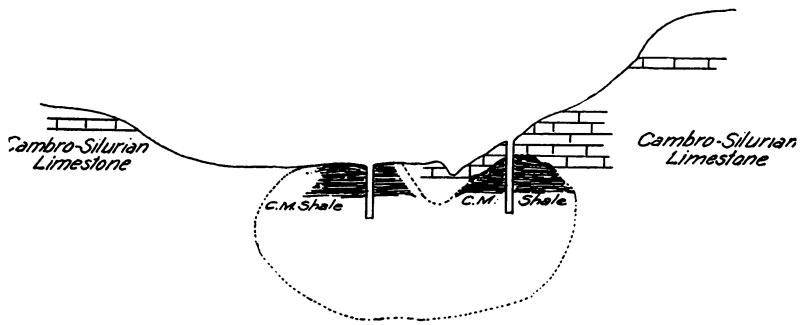

FIG. 3.—Cross-section—Son Prospect. Dotted line shows hypothetical extent of Coal-Measure shale.

portion of the uplift sandstone outcrops corresponding to them. If in the vicinity of the Osage the streams had run counter to the present channels, we would expect the resistant Cambro-Silurian rocks to preserve more filled channels crossing the present divides.

Cross-bedding and pebbles occur throughout the sandstone, and so deposition apparently kept pace with gradual depression. The first beds were perhaps deposited in estuaries, while later the whole land may have been submerged. From the probable geography of the time it may be suggested that the sand came from the south or southeast. From its lack of felspathic material, it was doubtless derived from the older Cambro-Silurian sandstones, and not from the granites of southeast Missouri.

After the deposition of the Graydon sandstone the land was again uplifted.

RÉSUMÉ.

On the north slope of the Ozark uplift the Burlington (in places the Chouteau) limestone rests unconformably upon the Cambro-Silurian formations, and the Pennsylvanian formations, in turn, rest unconformably upon the Burlington limestone and the Cambro-Silurian rocks. During the late Mississippian period, solution was unusually active, and the Saline Creek cave-conglomerate and Coal-Measure shale lie largely in solution cavities, developed previous to their deposition. The Graydon sandstone, when it rests on Cambro-Silurian rock, occupies normal erosion valleys. The present position and extent of the Carboniferous deposits is determined by several factors, among which the pre-Carboniferous and inter-Carboniferous land surfaces and post-Carboniferous erosion are important.

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